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ANALYSIS OF THE POLICIES FOR PROMOTING ELECTRICITY FROM RENEWABLE ENERGY SOURCES USING COMPUTABLE GENERAL EQUILIBRIUM MODEL -IN CASE OF PHOTOVOLTAIC SYSTEM-

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Abstract

Renewable energy (Solar power, Wind Power, Biomass, etc) is a power generation system which does not discharge carbon dioxide in its process. Nowaday, it attracts attention as an effective mean to construct a sustainalbe energy system. In European Union and the United States, various policies spreading renewable energy in electricity market are being implemented with focusing mainly on obligation to buy the electric power generated by renewable energy. This paper overviews the renewable-energy policy inplemented in some countries, analyzes and evaluates the economical influence by the promotion policy for photovoltaics and wind power which spread in the future is expected. The economical influence of the measures on the difusion of renewable energy is analyzed by using the applied general equilibrium model. As a result, the introduction of the renewable energy is crucially affected by both the investment subsidy to the renewable energy technologies, that is financed by revenue form carbon tax, and the change of household's energy demand characteristic (consuming structure) which is derived from the increase of green consumers

KEYWORDS: *renewable energy(RE),Photovoltaic, Wind power, Applied General Equilibrium Model*

1. Introduction

Renewable energy (RE) technologies encompass the power generation systems that do not discharge carbon dioxide in the process of power generation. Renewable energy is expected to play a greater role as an effective mean for establishing sustainable energy supply systems. Typical renewable energy generation systems like photovoltaic (PV) or wind power have gradually penetrated the market. The amount of installed capacity of photovaltaic equipment in Japan is the largest in the world. However, the total electricity production from renewable energy sources in Japan is only a

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small part of the whole domestic electricity production in as well as in the world. In the long term, to prevent climate change, environmental degradation and resource depletion, the massive and continuous promotion of renewable energy is needed for the abatement of CO_2 emission in energy supply sector and electricity consumption.

In Europe and United States, governments have implemented policy packages with various societal experimental trials. The obligation of utility companies to purchase the electricity from renewable energy sources (RES-E) is an example. The result of this policy is that the share of RES-E in electricity supply has been successfully and rapidly increasing in these countries. In Japan, on the other hand, the progressive policies for renewable energy promotion, which are a variety of policies for renewable energy promotion and increase in the energy market, is needed urgently. It is necessary to carry out various policies to attain significant level of renewable energy penetration foster the renewable energy industry, which will be competitive in energy market.

Some Studies referred to the interaction between the penetration of renewable energy and its technological characteristics were made. Kosugi et al. (1998) estimated the amount of introduction of PV power generation system according to technological factors. Tsuchiya (1999), Syouda et al. (1999) forecasted the installation of PV and other renewable energy technologies and the reduction of system costs by learning curve. The effect of the installation of PV system and the introduction subsidy, carbon tax and "green electricity program" are estimated in the model based on the Input-Output table by Okushima et al. (2000). Input-Output analysis was applied to quantify the macroscopic CO_2 reduction by introduction of the provision above-mentioned under constraint of constant GDP. In these studies, it is evaluated how the renewable energy promoting policies affect the technical elements and installed capacity. The CO2 emission reduction was measured by using CO2-Input/Output table. However, the effect on the renewable energy industry by introducing some policies is not examined explicitly.

This paper is aimed at development of the analytical tool for exploring the effective policies for renewable energy generation systems and relevant industries such as chemical, machinery or construction industry.

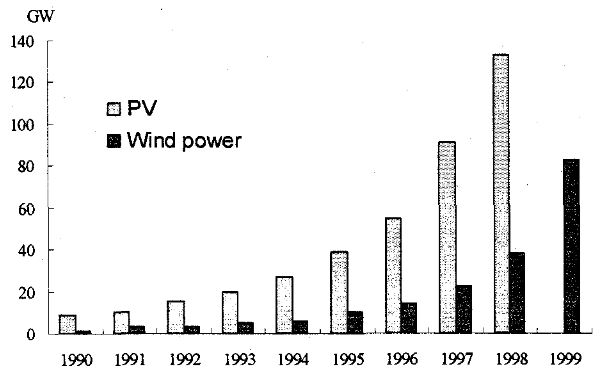
Firstly, in order to clarify the policies applicable to the analytical model, the current policies and measures for renewable energy have been classified through review of renewable energy policies in developed countries such as European countries or U.S.A. Then we examine the renewable energy policies impact on the domestic industries by using computable general equilibrium (CGE) model. In the analysis, the renewable energy technologies such as PV and wind power are considered. These technologies are expected to increase in the future.

2. The current situation of renewable energy: policy and measures on its promotion

In this chapter, we intend to review and classify the policies and measures for promoting RES-E.

2.1. Installed capacity of renewable energy and obstacles to its expansion

In Japan, the amount of installed capacity of photovoltaic and wind power is approximately 130MW and 38MW, respectively in 1998. Installation of both PV and wind power has been increasing rapidly in the last decade. The present targets of the government for PV and wind power are approximately 5GW and 300MW, respectively in 2010. Recently wind power installation has been growing so fast that the installation in 2010 can be beyond the target in 2010.



Source: New Energy and Indusrial Technology Development Organization (2000a),(2000b)

Figure 1. Installation of PV and Wind power in Japan

Table 1 shows that the obstacles to the installation of PV and wind power are categorized into four parts: institutional, economical, technical, and land use related issues. In the future, the renewable energy target and policy need to be revised in order to promote intensively and effectively the renewable energy to a large extent of the electricity consumption.

Table 1. The obstacles to the promotion of renewable energy[a)]

Obstacles	Photovoltaic	Wind Power
Institutional	• The lack of sufficient subsidy for each project of installation	• related laws and regulations call for the construction of incidental facilities such as roads or fences which is relatively expensive • complexities of system construction procedure approval
	• RES-E purchasing scheme does not ensure the return of investment to RE generation system due to the high system cost • The subsidy for renewable energy technologies is less than that for the conventional energy source such as fuel or nuclear in government budget	
Economic	• Cost of RES-E generation is higher than conventional generation because of relative high system cost	• The cost of additional strength of electric transmission equipment is needed if the windmill is constructed in the remote rural or coast areas
	• environmental cost is not reflected in the price of fossil fuels	
Technical	• Uncertainty of the volatile generation output of renewable energy cause the unstable frequency of the whole electricity in the transmission grid	

Land use	• In case that the systems are installed on the roof of collective housing, the problem for allocation of the electricity generated makes it difficult to install collective housing. • Large sized installation of PV system needs vast land area	• installation is limited by relevant laws and regulations • High cost of off shore installation (ex. Compensation for fishery, higher basic construction) • Mismatch of the distribution of wind resources and potential location

a) Table 1 is based on the interview with those relevant

2.2. Policies and measures for promotion of renewable energy

The policies and measure are classified as shown in Table 2.

Table 2. The classification of policies for renewable energy promotion

Obligation on the utilities to purchase RES-E[a)]		• The utility companies are obliged by law to connect private renewable energy generators to the grid and pay for RES-E a fixed feed-in tariff over the time.
Subsidy for capital investment costs or payment in line with electricity generation[a)]		• The government or other authorities subsidizes RE plant projects based on its generation capacity (yen/MW, yen/kW).
		• The government subsidizes purchase price of RES-E by utility companies (yen/kWh)
Tax credit[a)]		• The RE generators are credited for income so that they can cut their cash flows over time.
		• The RE generators are credited for investment tax so that they can reduce their capital cost.
Carbon tax[a)]		• It can raise the price of fossil fuels by internalizing the externalities of fuels. • Introduced in north European countries (Sweden, Norway, Denmark, Germany)
Green Pricing Schmes[b)]	Fund to Specific RE Project	• Consumers (individuals and private co-operatives etc.) pay an additional premium for the fund to specific RE project implemented by utility company. • The premium paid is not related to the RE capacity by project nor to the electricity production by project.
	Investment on specific RE project	• The voluntary electricity consumers immediately pay premium for investment of particular RE project.
	Choice of generation source (contains RE)	• By this system, the consumers can choose their electricity generation source. That could be more expensive than usual electricity price in liberalized electricity market.

Tradable Green Certificates (TGCs)[c]	• All renewable generators are certified for producing green electricity. They will get a green certificate per unit of electricity produced. This certificate can be sold to distribution companies or other electricity consumers who will have the obligation to cover a certain share of their electricity consumption. The payment for certificate can be interpreted as the premium and full cost for RES-E.
Renewable energy Portfolio Standard (RPS)[d]	• This is the scheme adopted in some states of the U.S. The retail sellers of electricity are obliged to include in their resource portfolio (that is the resources procured by the retail seller to supply its retail load) a certain amount of RES-E. The retailer can satisfy this obligation by either (a) owning a renewable energy facility and producing its own power, or (b) purchasing power from someone else's facility.

[a] T. Ackermann et al. (2001).
[b] B.Truffer et al. (2001).
[c] Morthorst (2000), Danish Energy Agency (1999).
[d] T. Berry et al. (2001), Espey. S (2000).

(1) Subsidy

The subsidy for power generation technology by renewable energy sources is seen in most of the industrialized countries that has phased out those for wind power considering cost reduction in recent years. The purpose of subsidy is mainly to subsidize for power generation technology by renewable energy sources and it falls into two categories; (a) subsidy for reducing the capital cost by RES-E generators for high system cost, (b) subsidy for supporting utilities purchasing RES-E by adding to feed-in tariff.

(2) Regulatory measures

The regulatory measures for promotion of renewable energy are likely to be adopted at the earlier stage when installed capacity of renewable energy generation system is at low level and the cost of electricity production from renewable energy sources are at high level. The regulatory measures contain the obligation; of the utility company (i. e. transmission and distribution system operators in the liberalized electricity market in U.K or Denmark) to purchase RES-E in fixed feed-in tariff. The contentions of this scheme are as follows;

- Who compensates the difference between the net electricity price and feed-in tariff, government or consumers?
- how is the feed-in tariff determined? Is it decided on the basis of the electricity price? or generation cost of RES-E?

It is argued that the fixed feed-in tariff scheme is putting great burden on the utilities through the payment to RES-E generators. Denmark, which has the second largest capacity of wind power generation system in the world, is in a transition period to competition-based scheme such as Tradable Green Certificates (TGC).

(3) Carbon tax

A carbon tax was introduced in north European countries, such as Denmark, Sweden. Many EU countries are considering the adoption of carbon tax or analogous means as an economic instrument for abatement of climate change or energy conservation, especially in the context of ecological or green tax reform. Some countries in Europe support renewable electricity via tax system. They take the form of (a) exemptions from tax payments or refunds of energy taxes where they exist, (b) lower VAT rates on some RES generation systems, like photovoltaic equipment, (c) tax exemptions for investments in small scale RES-E plans and (d) via the introduction of SO_2 and NOx taxes as in Denmark and Sweden where special favorable treatments are given to the development of wind and hydro power.

By internalizing the social cost derived from pollutant generated in fossil fuel combustion, the electricity price of "traditional" generation systems such as coal or oil power station may be raised and the RES-E can be able to compete with them. Some economists insist that the introduction of carbon tax can decrease the competitiveness of domestic industries. On the other hand, it is estimated that, if the carbon tax revenue is used to subsidize the introduction of energy saving technologies and CO2 emission mitigation technologies, the economic can grow significantly (e.g. Matsuoka et al. (1997a), Matsuoka et al. (1997b)).

(4) green pricing

Green pricing is a voluntary scheme recently introduced in north European countries and U.S.A. The consumers in industrialized countries are getting more interested in the environmental issues from regional level to global. The “green consumers”, who are conscious of the impact on the environment caused by their living, gained power recently and are likely to improve their life-styles by consuming environment-friendly commodities and practicing energy saving activities in their daily life. They also pursue the use of the electricity with low pollutant emission in generation.

The voluntary "green pricing" schemes appeared first in 1996 in Netherlands and Sweden, and now is spreading and being considered in other EU member states. In green pricing schemes, the consumers voluntarily opt to pay a premium for RES-E. The consumers pay part of the full extra costs that the generation of RES-E entails. Furthermore, they can volunteer to donate for renewable projects, or they can opt to take all their energy consumption through RES-E.

(5) use of the market mechanisms

Recently, the cost of wind power generation is decreasing significantly at a level competitive to conventional generation system such as coal or fuel power generation plants especially in Europe and U.S.

As there is more capacity installed, on the other hand, the financial burden of electric power utilities for the purchase of the electricity generation production from wind power increases and governmental financial support of renewable energy is getting excessive. In this context, support scheme by market mechanism for renewable energy is regarded as an effective measure to both expand consumption of RES-E and maximize the social economical efficiency. In several countries, where the capacity of "renewable" electricity production is growing, the measures for the renewable energy is shifting to market based mechanisms such as Tradable Green Certificates (TGC) or Renewable Energy Portfolio Standard (RPS) described above. In EU, the green certificates system is discussed in some countries. Such schemes might be adopted in more countries. In 2002, the government of Japan in turn decided to adopt the green certificate system to oblige electric power companies to cover the certain share of their electricity production by buying the certificate from producers of electricity from renewable energy sources from 2003.

3. Methodology

3.1. Computable General Equilibrium (CGE) model

In this article, we adopted the Computable General Equilibrium (CGE) model as an analytical tool. CGE model is often utilized for the simulations of the trading policy, public policy, tax system design, or environmental policy. CGE model is suitable to estimate the repercussion effect of policies and impact on national economy. In this paper, the method of a comparative static analysis, which is a relative simple CGE model, was executed.

3.2. Model structure

The model structure in this study is shown in Figure 2. The assumption is that there are household and enterprises as the major economic agent in the domestic area. In the following part of this chapter, we describe the structure of CGE model we constructed.

The CGE model we constructed mainly consists of two parts: economic agents' optimization problems (household's utility maximization and firms' profit maximization) and market clearing conditions. The behavioral assumptions of each economic agent in this model are described below.

(1) Household

It is assumed that the household maximizes their utility under given budget constraints. Here, the household is an aggregate agent that consists of the respective households.

The household's utility depends only on consumption of various consumable goods and is represented with a Cobb-Douglas type utility function. The household sells all of its primary factors to firms in order to buy consumable goods since the primary factors gives it no utility directly. The household saving is assumed to be a part of income of virtual economical agent "Investment" which consumes "investment goods".

(2) Production sectors

The assumption is given that firms produce consumable goods with input primary factors, labor and capital so that they maximize their profit and that each one of production sectors produce a single output. Firms produce the value added with input of labor and capital supplied by household. These factors are traded in a respective market. The value added production function is represented with a

Cobb-Douglas type production function in which both labor and capital are perfectly substitutable domestically between all production sectors. In Addition to the value added, the intermediate goods are incorporated in the production technology. Firms produce the goods by aggregating value added and intermediate goods. The production functions are assumed to be Leontief type production function.

The consumable goods are divided into the export goods and those domestically consumed. To produce consumable goods both corresponding to imported goods and domestically produced goods are used with production technology of a CES type production function. Additional firms who produce a composite good using domestically produced goods and a corresponding imported goods are assumed. Both imported and exported goods are traded in world market at fixed market prices.

The production functions, utility function and their constraints are formulated by introducing

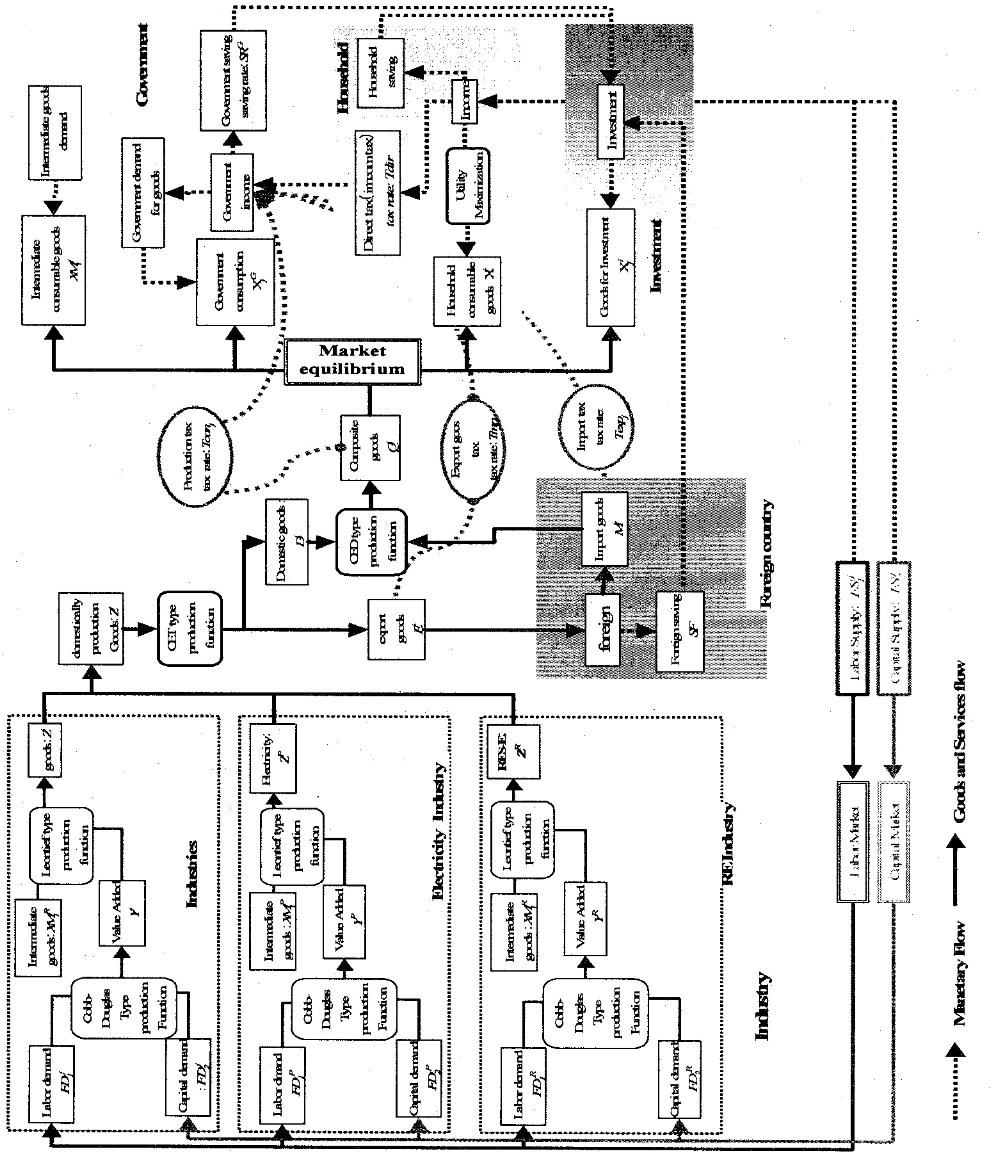


Figure 2. Model Structure

variety of parameters such as share parameters or substitution elasticity parameters and other exogenous parameters. We assume competitive markets for all goods and services. All firms produce with constant returns of scale and select output levels so that marginal cost equals the given market price.

(3) Government

In the model, as government behavior is assumed to be exogenous, government expenditures are fixed at benchmark levels, and it is assumed that government imposes production tax in ad quantum way on gross output and goods consumption. The government tax revenues finance the consumption of goods. The level of consumption of government is fixed at benchmark level.

(4) Investment

As the CGE model we constructed is a static model, we cannot incorporate idealistic investment behavior to this model. It is assumed that the quantity of investment is fixed and a virtual economic agent consumes investment goods subject to its budget constraint in order to maximize its utility. Whatever kind of assumption is employed as "investors" behavior, Investors' budget constraint should be fixed. In macro economic sense, his budget constraint is called investment balance.

(5) Market clearing conditions

Consumable goods and primary factors are demanded and supplied in the manner described above. To obtain the general equilibrium, the demand must be equal to the supply and a number of equations are equal to endogenous parameters.

3.3. Determination of initial data set

(1) Benchmark data of each domestic industry

To solve the model described above, the consumption of household and government and investment or input factor to each industry such as labor, capital and intermediate goods are needed to be displayed in the table called Social Accounting Matrix (SAM), which structure is similar to Input-Output table. Economic agents in Social Accounting Matrix are the industrial sectors classified as illustrated in Table 3: household, government, investment, import, and export. The initial benchmark data set of the model except for "PV" and "Wind power" is quoted and modified from 1995 Input-Output table and 1995 SNA in Japan. The input data consists of labor and capital, and the output factors are government and household consumptions, intermediate goods, export and import of each industry.

Table 3. Sector classification

Aggregated Sector Classification	93-Sector Classification
Agricultural, forestry and fishery	Crop cultivation, Livestock and sericulture, Agricultural services, Forestry, Fisheries
Mineral ores, Non-mineral ores	Mineral ores, Non-mineral ores
Food, Fabric and Paper/Pulp	Foods, Drinks, Feeds and organic fertilizer, Tobacco, Wearing apparel and other textile products, Timber and wooden products, Furniture and fixtures, Pulp, paper, paperboard and processed paper, Paper products, Publishing and printing
Chemical, Metal, steel	Chemical fertilizer, Inorganic basic chemical products, Petrochemical basic products and intermediate chemical products, Synthetic resins, Synthetic fibers, Medicaments, Final chemical products, Plastic products, Rubber products, Leather, fur skins and miscellaneous leather products, Glass and glass products, Cement and cement products, Pottery, china and earthenware, Other ceramic, stone and clay products, Pig iron and crude steel, Steel products, Steel castings and forgings and other steel products, Non-ferrous metals, Non-ferrous metal products, Metal products for construction and architecture, Other metal products,
Machinery	General industrial machinery, Special industrial machinery, Other general machines, Other general machines, Household electric appliance, 'Electronic equipment and communication equipment, Heavy electrical equipment, Other electrical machinery, Motor vehicles, Ships and repair of ships, Other transportation equipment and repair of transportation equipment, Precision instruments, 'Miscellaneous manufacturing products
Construction	Building construction, Repair of construction, Civil engineering
Fossil Fuel Production (Coal, petroleum, coal production, oil production)	Coal, Crude petroleum and natural gas, Petroleum refinery products, Coal products,
Electricity	Electricity
Photovoltaic[a]	
Wind power generation[a]	
Gas/Heat supply, Water service, Waste treatment	Gas and heat supply, Water supply, Waste disposal services
Commerce, Finance service, Insurance Banking, Real estate,	Commerce, Finance and insurance, Real estate agencies and rental services, House rent,
Transportation	Railway transport, Road transport (except transport by private cars), Transport by private cars, Water transport, Air transport, Freight forwarding, Storage facility services, Services relating to transport
Others	Communication, Broadcasting, Public administration, Education, Research, Medical service and health, Social security, Other public services, Advertising, survey and information services, Goods rental and leasing services, 'Repair of motor vehicles and machine, Amusement and recreational services, Eating and drinking places, Other personal services

[a] aggregated from existing Input-Output table and other statistics described in following subsection

(2) Estimation of Input-Output data of "PV" and "Wind power" industries

The renewable energy industries, "PV" and "Wind power" are assumed to produce electricity and have the same structures as other industries. The input and output data are estimated by disaggregation of the existing statistics.

The output data of "PV" and "Wind power" is determined as follows; part of the electricity produced from renewable energy is consumed at the site of production and the rest of RES-E is sold to the electric power companies through electricity distribution grid. The former is assumed by the household consumption of RES-E and the latter is assumed by the output to the electricity industry (Agency of Natural Resources and Energy, 1998) shown in Table 3. About two-third of the amount of power generation of PV serves as input to the "electricity" industry. And the remainder corresponds to the household's consumption of electricity from PV. As for Wind power, the household consumption equals to zero because utility companies bought all the electricity generated from wind power in 1995. Therefore, almost all of the output of "Wind power" sector equals to the input of "electricity" sector. The investment for "PV" and "Wind power" is assumed to equal to approximately 300 and 30 million yen respectively, the amount of subsidy of the government for PV and Wind power systems in 1995. The RES-E production is estimated according to the installed capacity and its annual average production. The payment of the utility company to renewable industries ("PV" and "Wind power" in Table 3) is calculated by multiplying the RES-E production by electric utility companies' RES-E purchasing price per kWh as shown in Table 4.

The total outputs of each renewable energy industry equals to the sum of the payment of utility companies and government's subsidy.

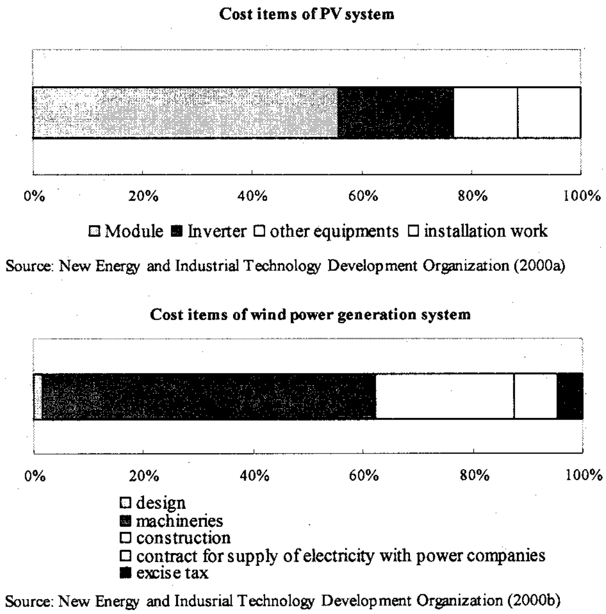


Figure 3. Cost items of renewable energy industries

Table 4. The generation capacity, electricity production and payment for production of "PV" and "Wind power"

	Cumulative installed capacity (GW)[a)]	Electricity production (Million kWh)	Payment of utility companies (Million yen)
Photovoltaic	39	38.73	968.2
Wind power	9.48	15.76	173.4

[a)] Agency of Natural Resources and Energy, Japan (1998),

The input data of renewable energy industry is determined as follows; the output of each industry to renewable energy industry is determined by allocating the sum of RES-E industry output for relevant industries in proportion to the average cost items such as construction, inverter, other equipments as shown in Figure3. The substitution of labor and capital and share parameter of value added production function of renewable energy industry is assumed to be the same of electricity industry. The import and export of renewable energy sectors are not assumed.

4. Analysis and results

4.1. Simulation cases

We set the three simulation cases showed in Table 5 on the basis of the review in Chapter 2.

Table 5. Simulation cases

Carbon tax	Carbon tax is imposed to the "fossil fuel" industry and its rate is expressd by varying exogenously the production tax (indirect tax) rate in the CGE model. The rate of carbon tax is determined by multiply the value of production by the CO2 emission in the respective industries derived from Moriguchi et al. (2000)	Carbon tax rate is varied as follows in reference to Matsuoka et al. (1997) ・5,000 yen/t-C ・10,000 yen/t-C ・20,000 yen/t-C ・30,000 yen/t-C
Subsidy for RES-E procuction	It is assumed that the demand for investment sector's consumption of "PV" electricity increase by varying the share parameter to the "PV" electricity of investment sector's consumption function. The percentage of expenditure to "PV" electricity of government consumption is fixed as intial condition.	The subsidy for the renewable energy industries such as "PV", "Wind power" is financed from. the revenue from carbon tax in line with the rate of cartbon tax mentioned above.
Diffusion of "Green electricity program"	It is assumed that the demand of the goods of houshold sector increase. The share parameter to RES-E such as "PV" of household consumption function is changed exogenously under the assumption that the household expentiture of RES-E increse in the "green electricity program" by electric power company.	The household's consumption drived from National Survey of Family Income and Expenditure (1995). The assumption is that the share of total electricity consumption in the household consumption is fixed.

In any of the cases above, the policy is represented by exogenously changing the parameters in the model. Carbon tax is expressed by changing the production tax (indirect tax) rate of "fossil fuel" industry. In the case of subsidy, the share parameter of investment sector is changed exogenously, and the share parameter of household's' consumption function is changed similarly in the case of "green electricity program".

The results are outlined as follows in the following subsections.

4.2. Using government revenue from carbon tax as the subsidies for the renewable energy industries

Here, the carbon tax, subsidy for renewable energy and voluntary pricing scheme are considered as measures for dissemination of renewable energy technologies. It is assumed that the government revenue from carbon tax is only used to subsidize the "PV" industry corresponding to the carbon tax rate. The result is illustrated in Figure 4.and Figure 5. The value of production of "PV" industry increases as carbon tax rate increases. Similarly, the share of RES-E in total electricity production including "electricity", "PV" and "Wind power" grew from 0.012% to 0.4%. The installed capacity of "PV" increased approximately 2GW in the 30,000 yen/t-C carbon tax case. The revenue of carbon tax in each tax rate is shown in Table 6.

It should be noticed that the amount of value of production and installed capacity of "PV" might be underestimated because the technological innovation arising from capital accumulation or improvement of production process are not considered in this static model.

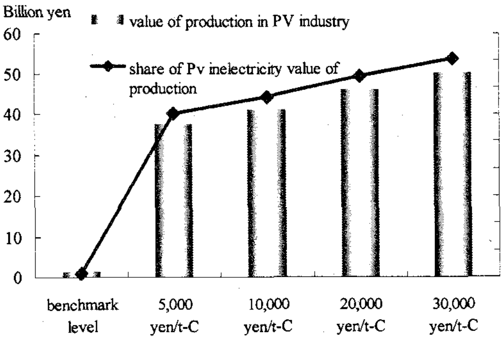


Figure 4. Value of production of "PV"

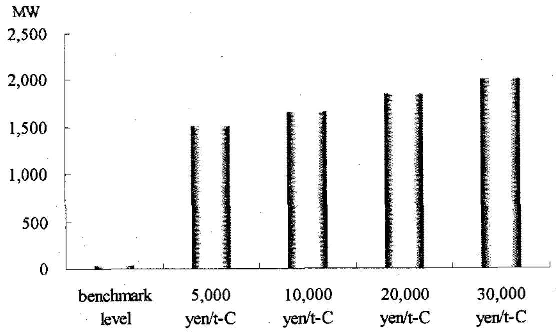


Figure 5. Installed capacity of "PV"

Table 6. Revenue from carbon tax

Tax rate	5,000 yen/t-C	10,000 yen/t-C	20,000 yen/t-C	30,000 yen/t-C
Revenue (Billion yen)	456	489	551	608

4.3. Diffusion of green electricity pricing scheme

Until now, households have traditionally consumed electricity from conventional power generation systems, e.g. coal or petroleum combustion, which discharged various pollutants such as CO_2, SO_2 and NOx. Recently, However, the emerging "green consumers" are likely to prefer "green electricity" generated by renewable energy sources.

Electricity liberalization and these consumers' awareness of environmentally friendly electricity could be the pressures that urge the electric company to promote the "green power marketing". The simulation case here assumes that "green electricity scheme" mentioned in 2.1 is introduced nation wide in Japan, and that the 0.5%-3% of the whole household accepts a "green electricity scheme" to pay 500 yen as a donation to fund in addition to each household's expenditure of electricity in every month.

The result of simulation is shown in Figure 6 and Figure 7. Value of production of "PV" industry increases from 1.4 billion yen in base case to more than 10 billion yen in the case of 3% participation in "green electricity program". Similarly, the share of "PV" in the whole of electricity industries ("electricity", "PV" and "wind power") also grows from 39 MW to around 400 MW. There is a possibility of underestimating the growth of production and capacity due to the same reason in the simulation case of carbon tax.

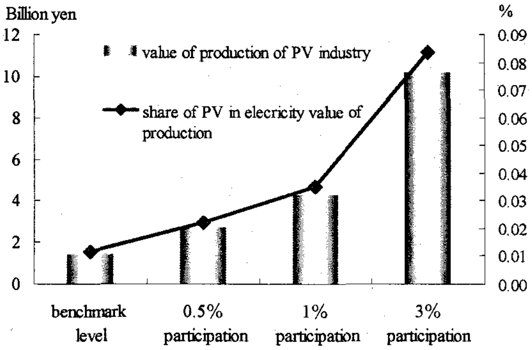


Figure 6. Value of production of "PV"

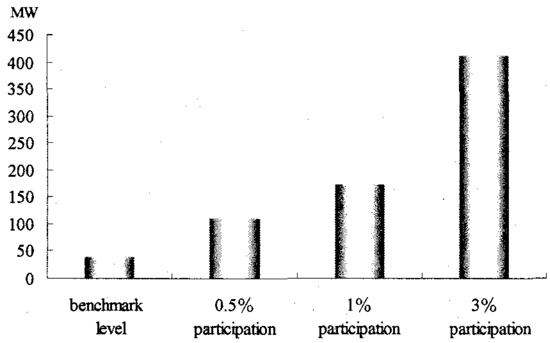


Figure 7. Installed capacity of "PV"

5. Summary

In this paper, we have focused on how some measures for promotion of electricity generated from the renewable energy technology of photovoltaic have impacts on the industry from macroeconomic perspective by using CGE model.

In the case of carbon tax only, the production of the whole industry decreased, although the production of each industry varied due to its carbon intensity.

When the carbon tax revenue is allocated only to subsidy for "PV" industry, the production of the "PV" industry increased drastically and the share of the whole electricity production (i.e. "electricity", "PV" and "Wind power") correspondingly increased too.

When the green electricity scheme is introduced in the household sector, the production of "PV" industry increased by the direct effect of the transformation of consumer propensity to this type of electricity. The measures stimulating consumers, such as "green electricity scheme", could be expected to be an effective action for expanding the consumption of RES-E by end-user of electricity. The additional investment could be necessary to the new type of initiatives like "green electricity scheme". The burden sharing of additional cost of the policies or measures introduced for the purpose of promoting RES-E, in accordance with a CO2 emission of each economic shareholder, are effective and efficient.

The method of analysis mentioned above is applicable to quantify how effective and efficient the renewable energy policy is from an economical point of view.

Finally, we will work on the following tasks in the future:

In the current model, as the substitution between the "green" electricity (RES-E) and the "conventional" or "traditional" electricity is not taken into account, the results are affected mainly by the structural difference between "PV" and "electricity" industries. In order to consider the substitution between different energy systems including renewable energy sources, the energy input as factors in addition to the labor, capital and intermediate goods in productions in each industrial sectors must be incorporated and the relevant parameters like elasticity of substitution in either production or consumption function must be modified so that the model can capture the recent growth of Photovoltaic and Wind power generation system.

As the power generation systems from renewable energy sources are capital intensive and still infant technologies in Japan, it is necessary to take into consideration the long-run effect of capital accumulation in such growing energy production sectors.

Furthermore, determine how the expansion of consumers' green purchasing changes the structure of production process in related industries, especially energy production industries. Determine, also, influence how this expansion influences the transformation of consumption and production as well as the future energy supply-demand systems and the CO_2 abatement cost in the future. From these points of view, the dynamic model is needed in a further analysis of the policies for long-term promotion of renewable energies.

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